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Fujita et al.

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(54) **VARIABLE DISPLACEMENT VANE PUMP**

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F04B 49/00 (2006.01)

(52) **U.S. Cl.** **417/310**; 417/220

(58) **Field of Classification Search** 417/220, 417/310; 418/30

See application file for complete search history.

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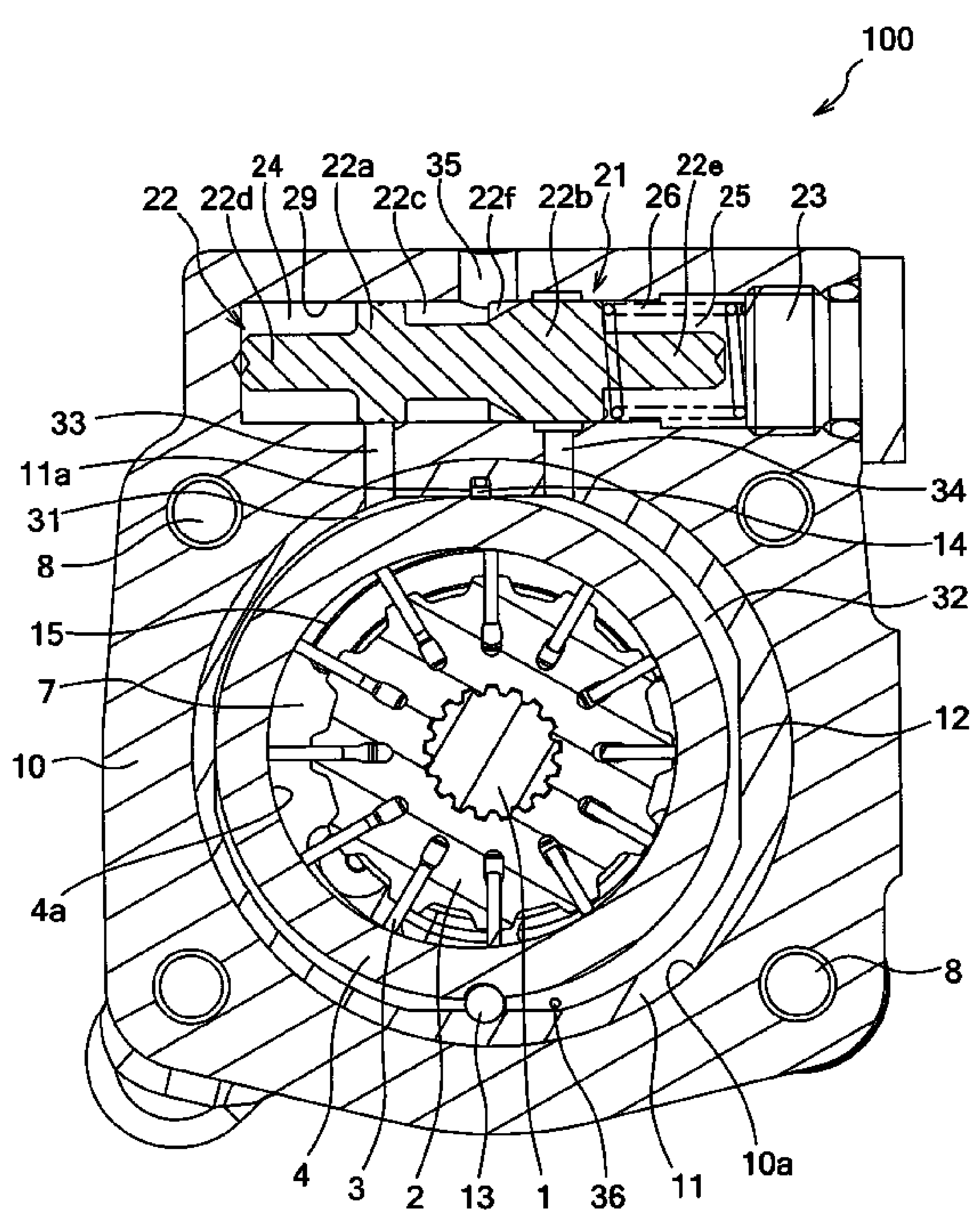
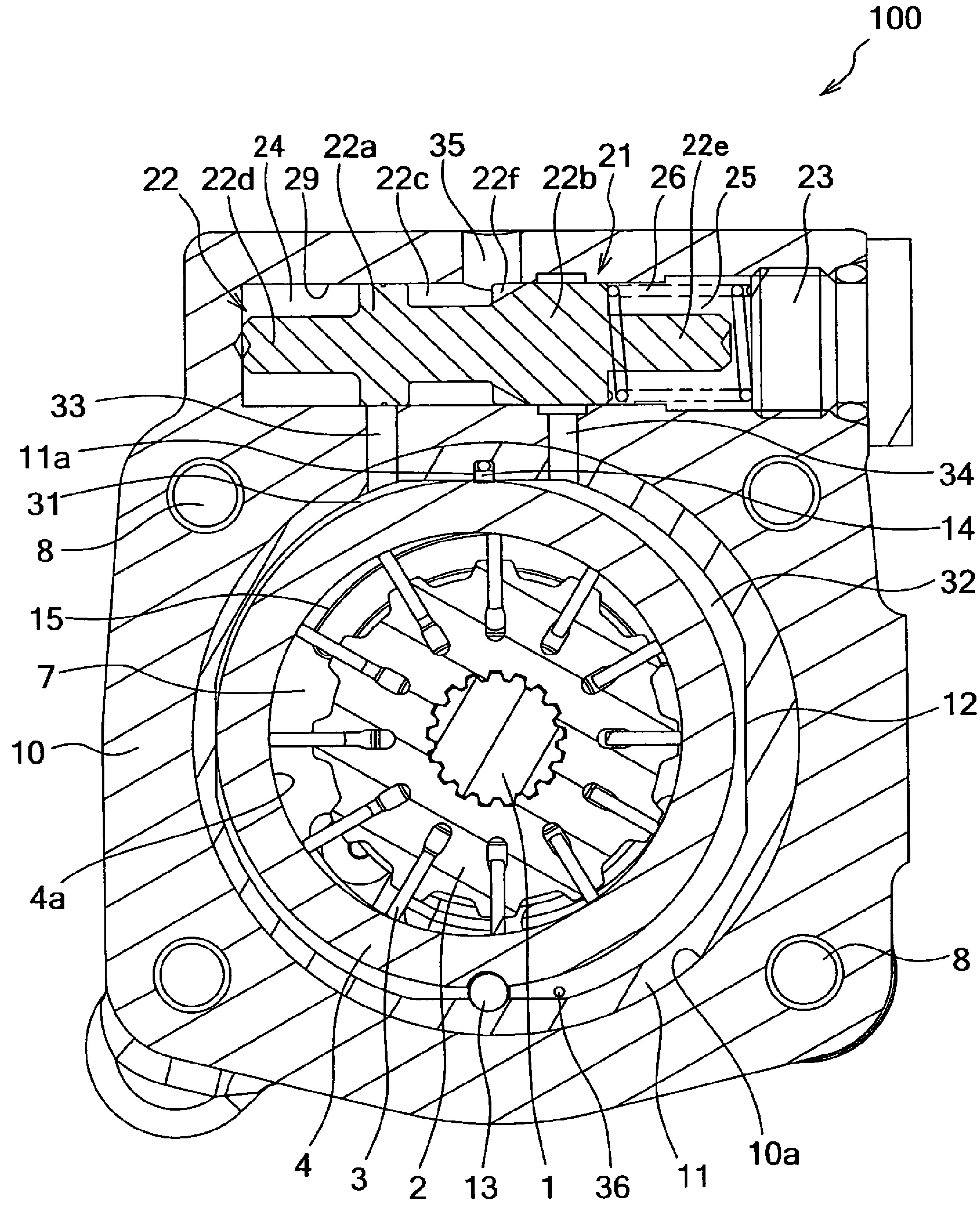
(57) **ABSTRACT**

A variable displacement vane pump includes a first and a second fluid pressure chamber (**31**,**32**) where the cam ring (**4**) is made eccentric to the rotor (**2**) by a pressure difference between the first and the second fluid pressure chamber (**31**, **32**), a control valve (**21**) for controlling a pressure of the first and the second fluid pressure chamber (**31**,**32**) so that an eccentric amount of the cam ring (**4**) is reduced to be small with an increase in a rotation speed of the rotor (**2**), and a flow amount limiting member (**22***e*) for limiting a discharge flow amount of the operating fluid in the second fluid pressure chamber (**32**) at the time the eccentric amount of the cam ring (**4**) to the rotor (**2**) becomes small by supplying the operating fluid to the first fluid pressure chamber (**31**) and by discharging the operating fluid from the second fluid pressure chamber (**32**).

4 Claims, 10 Drawing Sheets





100
22
22d
24
29
22a
22c
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22f
22b
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26
22e
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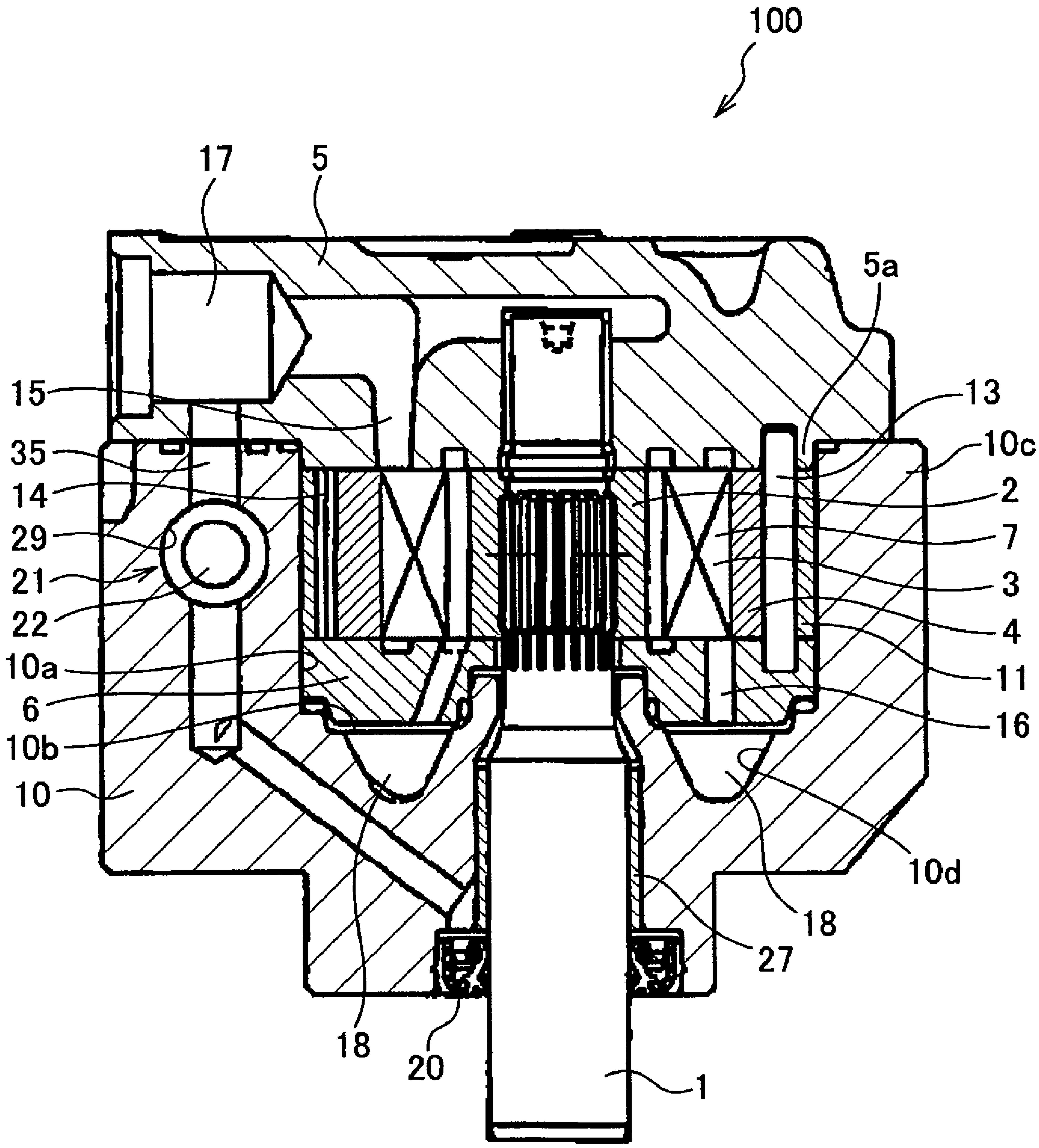
23
33
11a
31
8
15
7
10
4a
34
14
32
12
8
4
3
2
13
1
36
11
10a

FIG.1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14
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29
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10a
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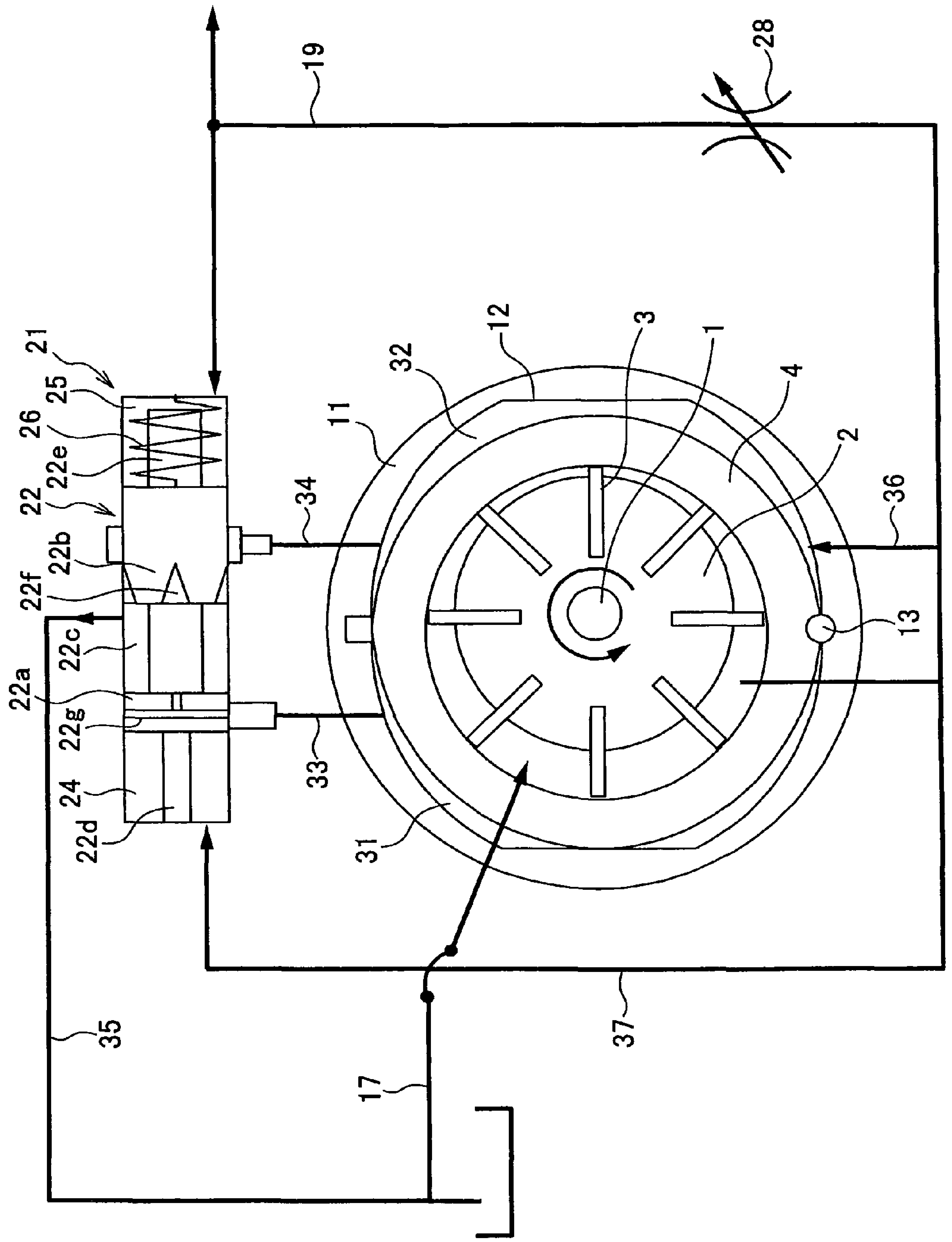
10b
10
10d
18
27
18
20
1

FIG.2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33
31
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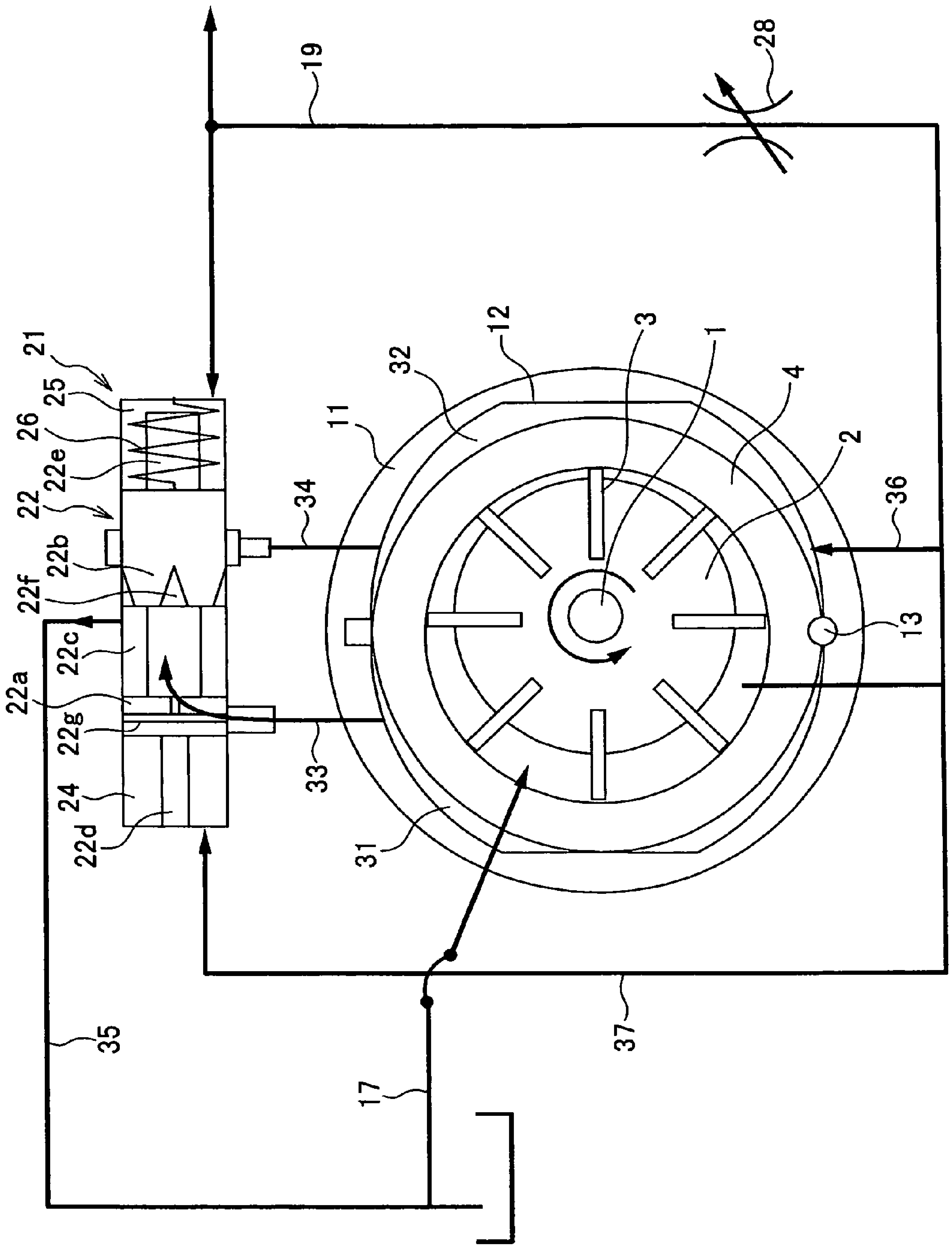
17

FIG.3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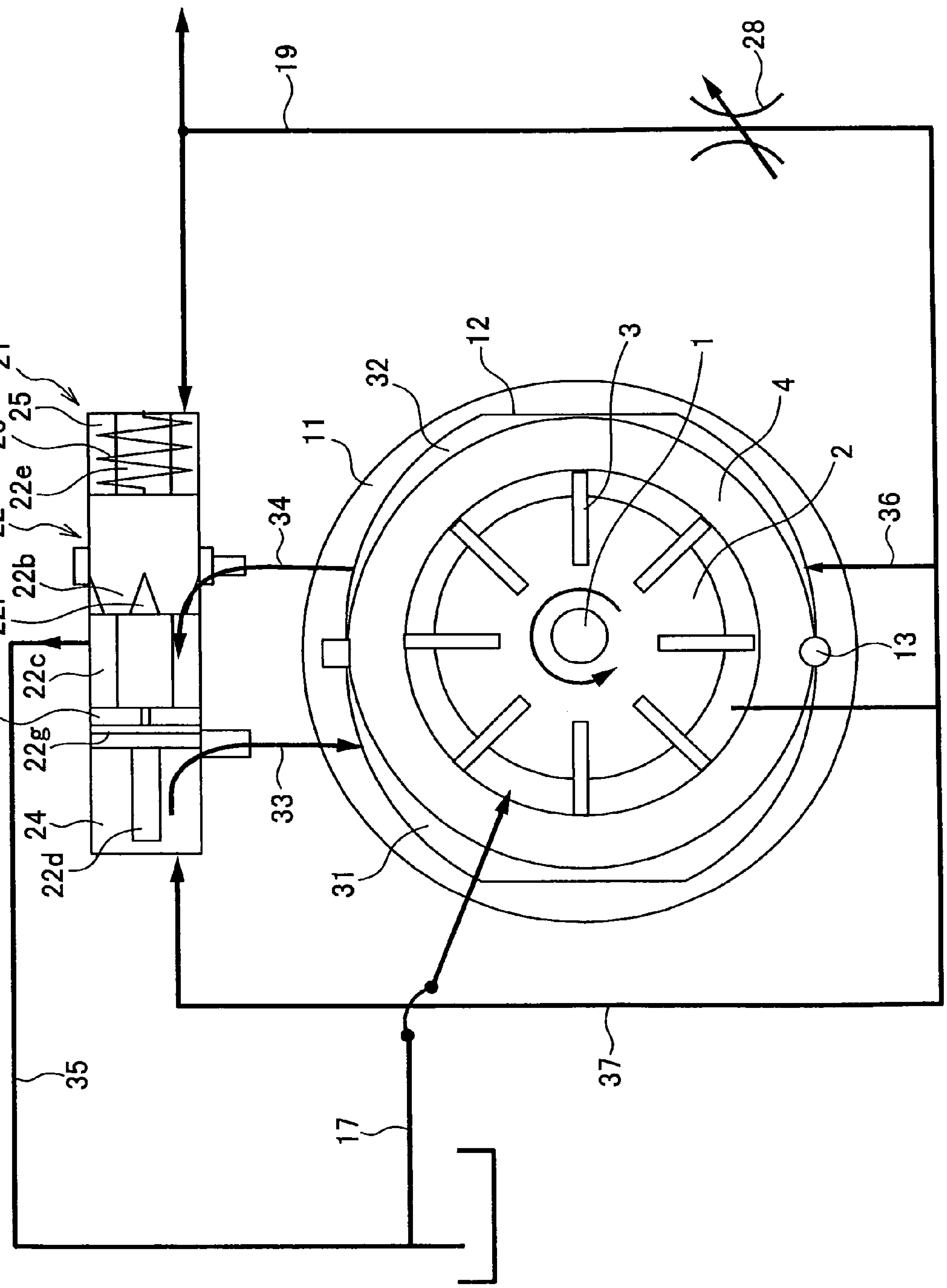
31

FIG.4



19
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32
12
3
1
4
2
36
13

FIG.5

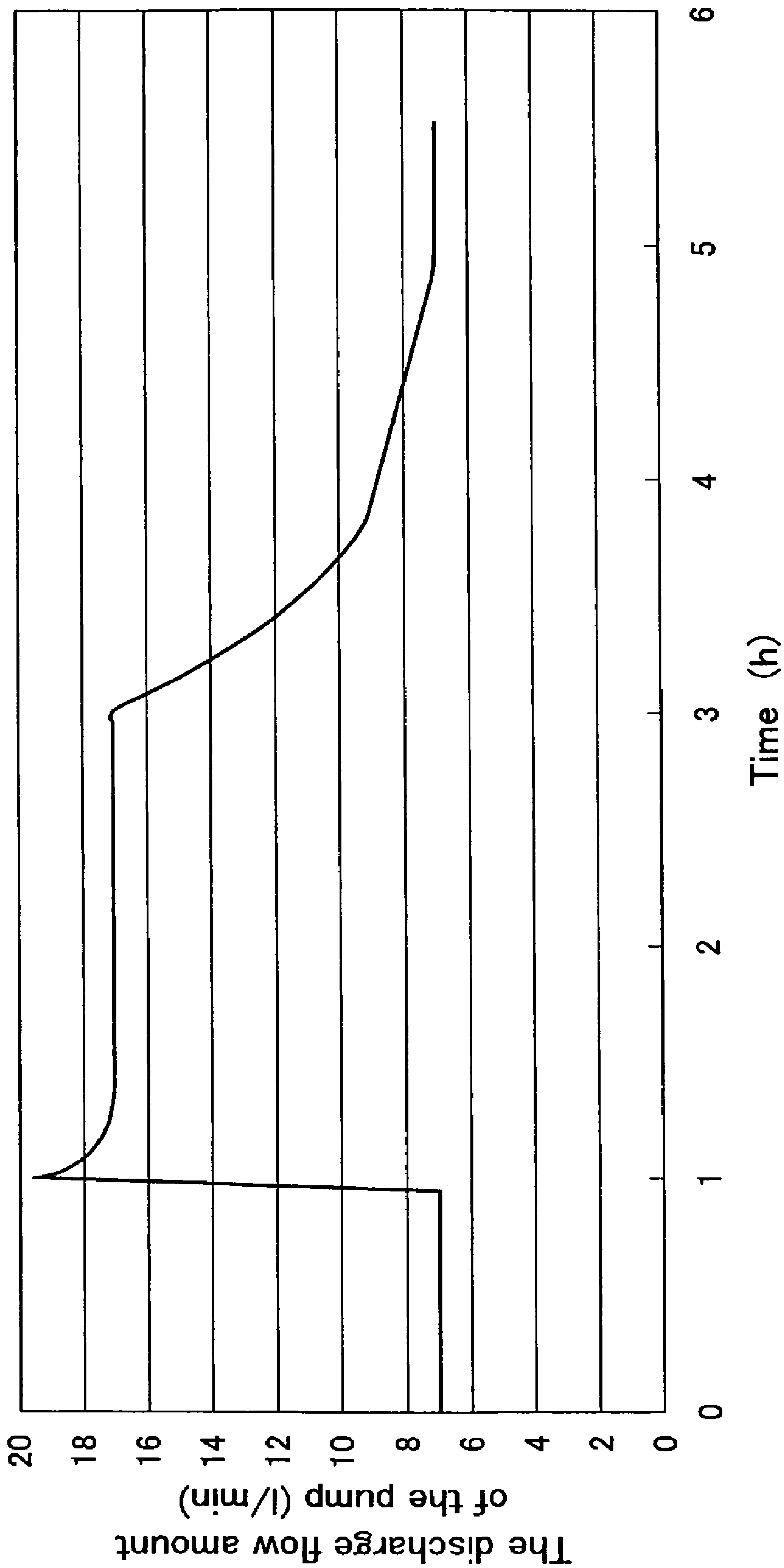
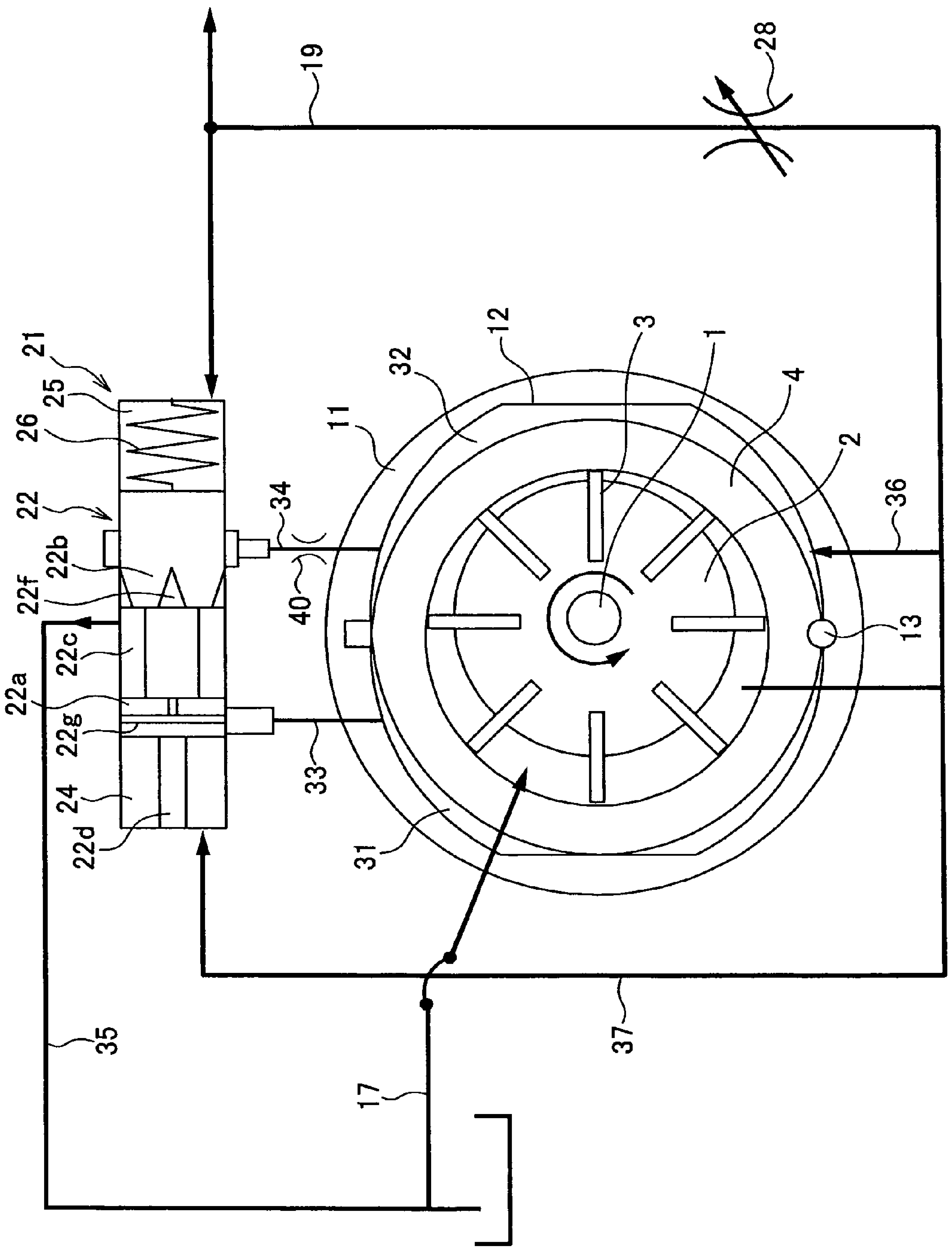

The discharge flow amount
of the pump (l/min)
0
2
4
6
8
10
12
14
16
18
20
Time (h)
0
1
2
3
4
5
6

FIG.6



19
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3
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4
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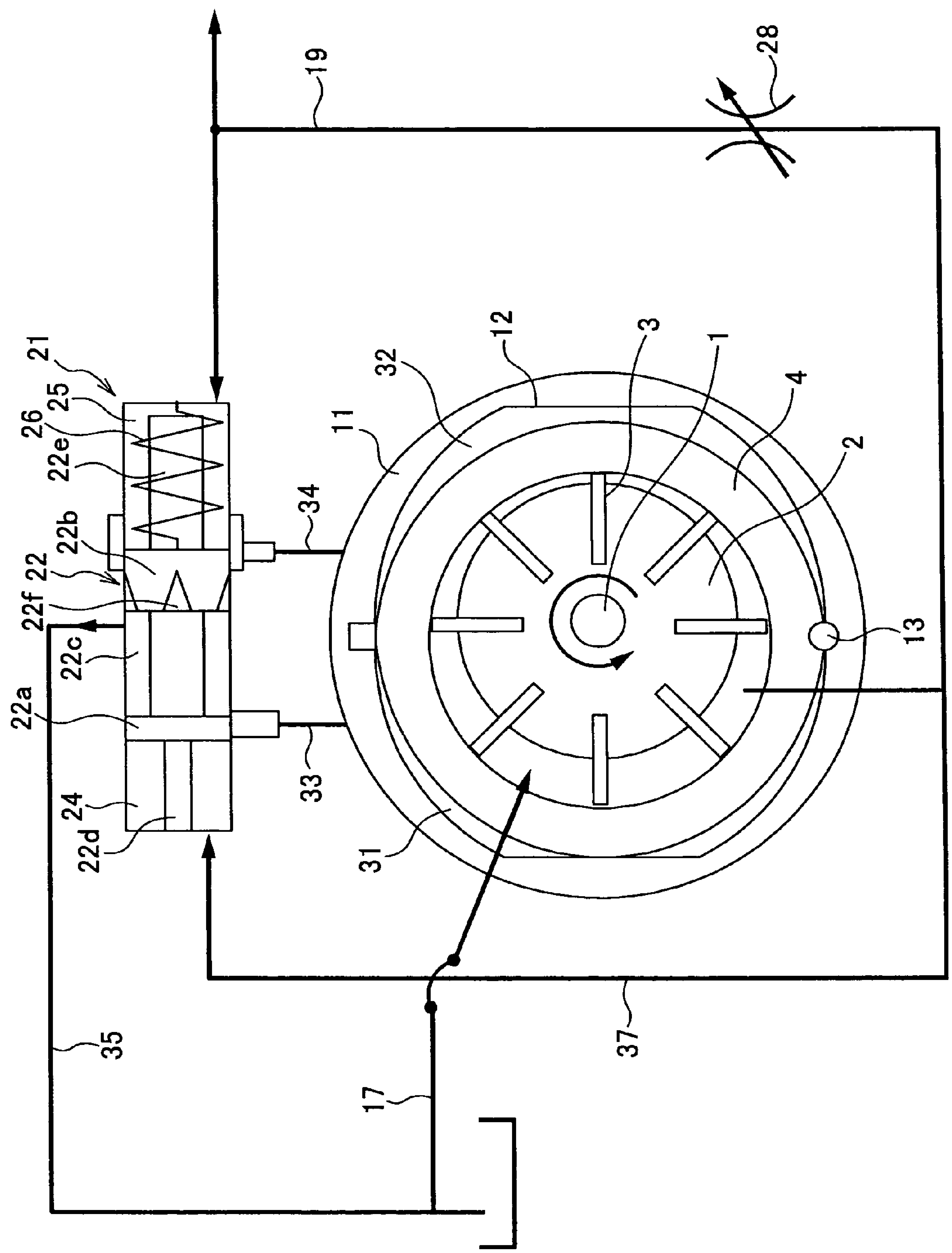
36
13

FIG.7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22f
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35
37

FIG.8

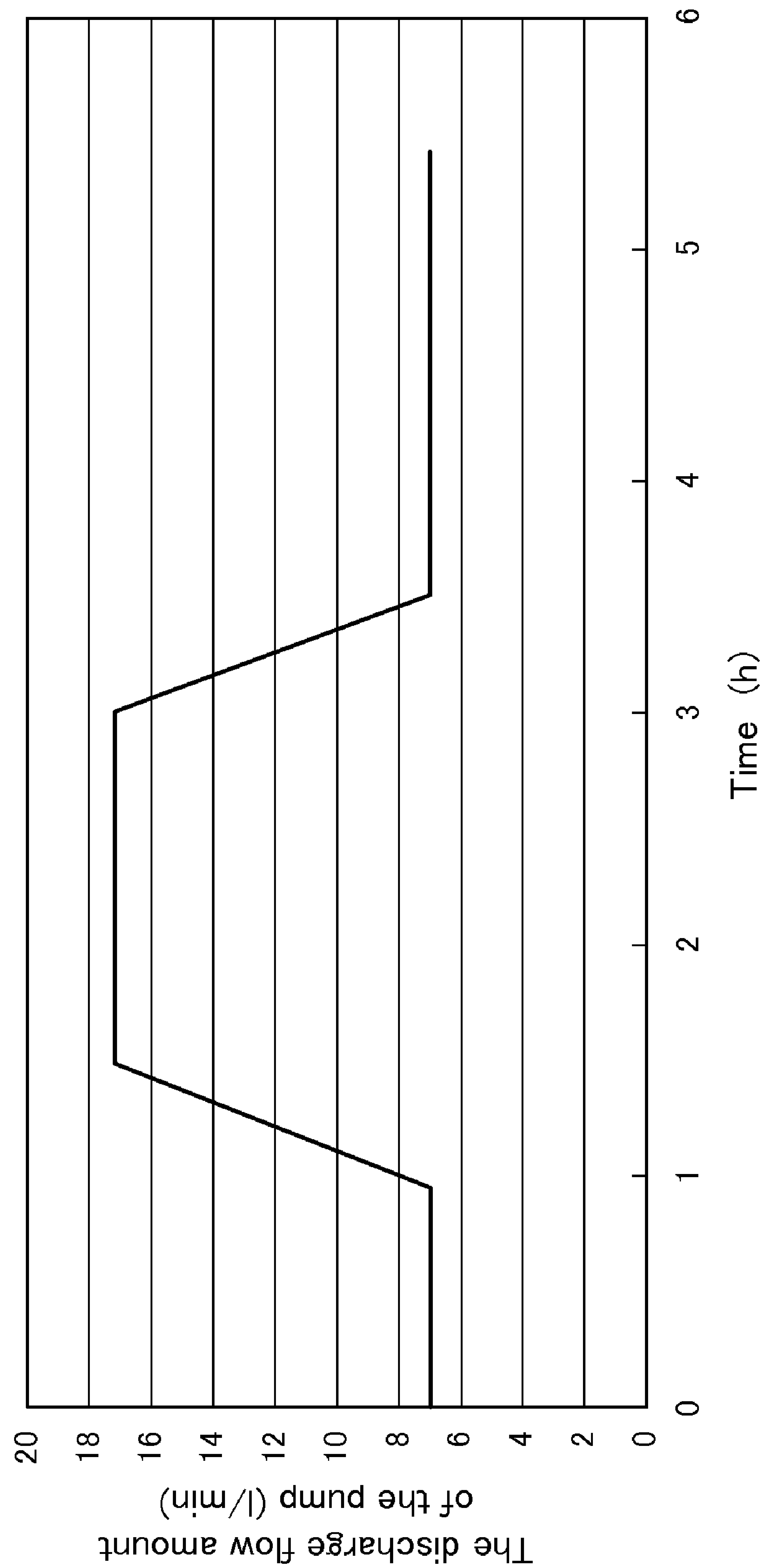

FIG.9 PRIOR ART

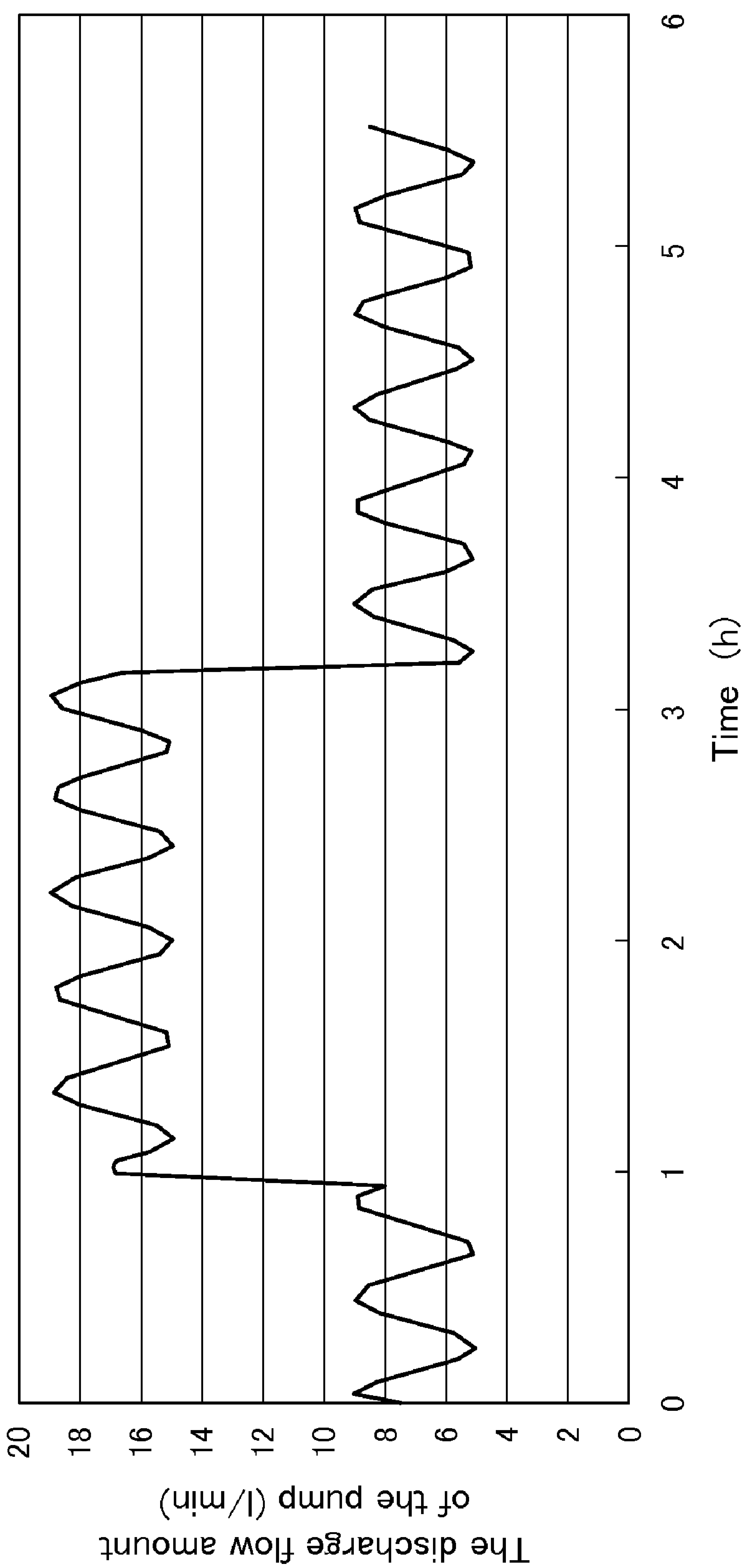

FIG.10 PRIOR ART

VARIABLE DISPLACEMENT VANE PUMP

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a variable displacement vane pump used as a hydraulic supply source in hydraulic equipment.

DESCRIPTION OF RELATED ART

A conventional variable displacement vane pump changes a pump discharge displacement by changing an eccentric amount of a cam ring to a rotor.

JP8-200239A discloses a pump which is provided with a first fluid pressure chamber **36** and a second fluid pressure chamber **37** formed in a outer peripheral side of a cam ring **17** for moving and displacing the cam ring **17** and a control valve **30** of a spool type for controlling a supply fluid pressure to each fluid pressure chamber **36** and **37** in accordance with a discharge amount of the pressurized fluid from a pump chamber. The pump disclosed in JP8-200239A is, for restricting an oscillation phenomenon of the cam ring **17**, provided with a first orifice **50**, a second orifice **51** and a third orifice **52** located in fluid passages **46** and **47** leading from a pump discharge side to one chamber **32***a* of the control valve **30** and in fluid passages **35** and **19***b* leading from the control valve **30** to the first fluid pressure chamber **36**.

SUMMARY OF THE INVENTION

In the pump disclosed in JP8-200239A, however, when the cam ring **17** moves in a direction of increasing an eccentric amount to a rotor **15**, since the fluid in the first fluid pressure chamber **36** is subjected to resistance caused by the orifice **52** interposed in the fluid passages **35** and **19***b* leading from the control valve **30** to the first fluid chamber **36**, it is difficult for the fluid to be discharged from the first fluid pressure chamber **36**. Therefore, as shown in FIG. **9**, the response at the time of increasing the discharge flow amount of the pump is degraded.

Therefore, when the orifice **52** is removed for improving the response at the time of increasing the discharge flow amount of the pump, the response at the time of increasing the discharge flow amount of the pump is, as shown in FIG. **10**, improved, but the flow amount change is increased, causing the difficulty in restricting the oscillation phenomenon of the discharge flow amount.

The present invention is made in view of the foregoing problem and an object of the present invention is to provide a variable displacement vane pump which can restrict an oscillation of a discharge flow amount and improve the response at the time of increasing the discharge flow amount of the pump.

In order to achieve above object, the present invention provides a variable displacement vane pump having a rotor connected to a drive shaft, a plurality of vanes provided in the rotor so as to be capable of reciprocating in a diameter direction of the rotor, a cam ring for accommodating the rotor therein, the cam ring having a cam face in an inner surface thereof on which a front portion of the vane slides by rotation of the rotor and being made eccentric to a center of the rotor, and a pump chamber defined between the rotor and the cam ring, wherein an eccentric amount of the cam ring to the rotor changes, thereby changing a discharge displacement of the pump chamber. The variable displacement vane pump comprises a first fluid pressure chamber and a second fluid pressure chamber which are defined in an accommodating space in the outer periphery of the cam ring, wherein the cam ring is made eccentric to the rotor by a pressure difference between the first fluid pressure chamber and the second fluid pressure chamber, a control valve which operates in response to a pump discharge pressure for controlling a pressure of an operating fluid in each of the first fluid pressure chamber and the second fluid pressure chamber in such a manner that the eccentric amount of the cam ring to the rotor becomes small with an increase in a rotation speed of the rotor, and a flow amount limiting member for limiting a discharge flow amount of the operating fluid in the second fluid pressure chamber at the time the eccentric amount of the cam ring to the rotor becomes small by supplying the operating fluid to the first fluid pressure chamber and discharging the operating fluid from the second fluid pressure chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional view showing a cross section perpendicular to a dive shaft in a variable displacement vane pump according to an embodiment in the present invention.

FIG. **2** is a cross-sectional view showing a cross section in parallel to the dive shaft in the variable displacement vane pump according to the embodiment in the present invention.

FIG. **3** is a hydraulic circuit diagram in the variable displacement vane pump according to the embodiment in the present invention.

FIG. **4** is a hydraulic circuit diagram at the maximum discharge flow amount in the variable displacement vane pump according to the embodiment in the present invention.

FIG. **5** is a hydraulic circuit diagram at the minimum discharge flow amount in the variable displacement vane pump according to the embodiment in the present invention.

FIG. **6** is a graph showing a discharge flow amount characteristic in the variable displacement vane pump according to the embodiment in the present invention.

FIG. **7** is a hydraulic circuit diagram in a variable displacement vane pump according to a different embodiment in the present invention.

FIG. **8** is a hydraulic circuit diagram in the variable displacement vane pump according to the different embodiment in the present invention.

FIG. **9** is a graph showing a discharge flow amount characteristic in the conventional variable displacement vane pump.

FIG. **10** is a graph showing the discharge flow amount characteristic in the conventional variable displacement vane pump.

PREFERRED EMBODIMENTS OF THE INVENTION

Hereinafter, an embodiment in the present invention will be explained with reference to the accompanying drawings.

A variable displacement vane pump **100** according to an embodiment in the present invention will be explained with reference to FIGS. **1** to **3**. The variable displacement vane pump **100** (hereinafter, referred to as "vane pump" simply) is used as a hydraulic supply source for hydraulic equipment mounted in a vehicle. The hydraulic equipment is, for example, a power steering apparatus or a transmission.

In the vane pump **100**, power of an engine (not shown) is transmitted to a drive shaft **1** and thereby a rotor **2** connected to the drive shaft **1** rotates. The rotor **2** rotates in a counter-clockwise direction in FIG. **1**.

The vane pump **100** is provided with a plurality of vanes **3** provided in the rotor **2** so as to be capable of reciprocating in the diameter direction of the rotor **2**, and a cam ring **4** which accommodates the rotor **2** therein where a front portion of the vane **3** is in sliding contact with a cam face **4***a* constituting an inner periphery of the cam ring **4** by rotation of the rotor **2** and the cam ring **4** is eccentric to a center of the rotor **2**.

The drive shaft **1** is supported through a bush **27** (refer to FIG. **2**) to a pump body **10** so as to rotate freely thereto. The pump body **10** is provided with a pump accommodating concave portion **10***a* formed therein for accommodating the cam ring **4**. A seal **20** is provided at an end of the pump body **10** for preventing a leak of lubricant between an outer periphery of the drive shaft **1** and an inner periphery of the bush **27**.

A side plate **6** is arranged in a bottom surface **10***b* of the pump accommodating concave portion **10***a* and abuts on one end portion of each of the rotor **2** and the cam ring **4**. An opening of the pump accommodating concave portion **10***a* is closed by a pump cover **5** abutting on the other end portion of each of the rotor **2** and the cam ring **4**. The pump cover **5** is provided with a circular fitting portion **5***a* formed therein for being fitted into the pump accommodating concave portion **10***a* where an end surface of the fitting portion **5***a* abuts on the other end portion of each of the rotor **2** and the cam ring **4**. The pump cover **5** is fastened to a ring-shaped skirt portion **10***c* of the pump body **10** by bolts **8**.

In this way, the pump cover **5** and the side plate **6** are arranged in such a manner as to sandwich both side surfaces of each of the rotor **2** and the cam ring **4**. In consequence, pump chambers **7** are defined to be partitioned by the respective vanes **3** between the rotor **2** and the cam ring **4**.

The cam ring **4** is a ring-shaped member and has a suction region for expanding a displacement of the pump chamber **7** partitioned by and between the respective vanes **3** by rotation of the rotor **2** and a discharge region for contracting the displacement of the pump chamber **7** partitioned by and between the respective vanes **3** by rotation of the rotor **2**. The pump chamber **7** suctions an operating oil (operating fluid) in the suction region and discharges the operating oil in the discharge region. In FIG. **1**, a part above a horizontal line passing through a center of the cam ring **4** shows the suction region and a part under the horizontal line shows the discharge region.

A ring-shaped adapter ring **11** is fitted onto an inner peripheral surface of the pump accommodating concave portion **10***a* in such a manner as to surround the cam ring **4**. The adapter ring **11** has both side surfaces sandwiched by the pump cover **5** and the side plate **6** in the same way as the rotor **2** and the cam ring **4**.

A support pin **13** is supported on an inner peripheral surface of the adapter ring **11** and extends in parallel with the drive shaft **1**, and both ends of the support pin **13** each are inserted into the pump cover **5** and the side plate **6**. The cam ring **4** is supported by the support pin **13**, and the cam ring **4** swings around the support pin **13** as a supporting point inside the adapter ring **11**.

Since the support pin **13** has both ends each inserted into the pump cover **5** and the side plate **6** and supports the cam ring **4**, the support pin **13** restricts a relative rotation of the pump cover **5** and the side plate **6** to the cam ring **4**.

A groove **11***a* extending in parallel with the drive shaft **1** is formed in the inner peripheral surface of the adapter ring **11** at a position axisymmetric to the support pin **13**. A seal member **14** is attached in the groove **11***a* to be in sliding contact with an outer peripheral surface of the cam ring **4** at the swinging of the cam ring **4**.

A first fluid pressure chamber **31** and a second fluid pressure chamber **32** are defined in a space between the outer peripheral surface of the cam ring **4** and the inner peripheral surface of the adapter ring **11** by the support pin **13** and the seal member **14**, which is an accommodating space in the outer periphery of the cam ring **4**.

The cam ring **4** swings around the support pin **13** as a supporting point caused by a pressure difference in operation oil between the first fluid pressure chamber **31** and the second fluid pressure chamber **32**. When the cam ring **4** swings around the support pin **13** as the supporting point, an eccentric amount of the cam ring **4** to the rotor **2** changes to change a discharge displacement of the pump chamber **7**. In a case where a pressure in the first fluid pressure chamber **31** is larger than a pressure in the second fluid pressure chamber **32**, the eccentric amount of the cam ring **4** to the rotor **2** is reduced, so that the discharge displacement of the pump chamber **7** becomes small. In contrast, in a case where the pressure in the second fluid pressure chamber **32** is larger than the pressure in the first fluid pressure chamber **31**, the eccentric amount of the cam ring **4** to the rotor **2** is increased, so that the discharge displacement of the pump chamber **7** becomes large. In this way, in the vane pump **100**, the eccentric amount of the cam ring **4** to the rotor **2** changes caused by the pressure difference between the first fluid pressure chamber **31** and the second fluid pressure chamber **32**, thereby changing the discharge displacement of the pump chamber **7**.

A swelling portion **12** is formed on the inner peripheral surface of the adapter ring **11** in the second fluid pressure chamber **32**. The swelling portion **12** serves as a cam ring movement restricting member for restricting the movement of the cam ring **4** in a direction of decreasing the eccentric amount of the cam ring **4** to the rotor **2**. The swelling portion **12** defines the minimum eccentric amount of the cam ring **4** to the rotor **2** and maintains a state where an axis center of the rotor **2** is shifted from an axis center of the cam ring **4** in a state where the outer peripheral surface of the cam ring **4** abuts on the swelling portion **12**.

The swelling portion **12** is formed so that the eccentric amount of the cam ring **4** to the rotor **2** does not become a zero. That is, the swelling portion **12** is configured so that even in a state where the outer peripheral surface of the cam ring **4** abuts on the swelling portion **12**, the minimum eccentric amount of the cam ring **4** to the rotor **2** is ensured, causing the pump chamber **7** to discharge the operating oil. In this way, the swelling portion **12** secures the minimum discharge displacement of the pump chamber **7**.

It should be noted that the swelling portion **12** may be formed on the outer peripheral surface of the cam ring **4** in the second fluid pressure chamber **32** instead of being formed on the inner peripheral surface of the adapter ring **11**. In addition, in a case where the first fluid pressure chamber **31** and the second fluid pressure chamber **32** are defined between the outer peripheral surface of the cam ring **4** and the inner peripheral surface of the pump accommodating concave portion **10***a* without providing the adapter ring **11**, the swelling portion **12** may be formed on the inner peripheral surface of the pump accommodating concave portion **10***a*.

The pump cover **5** is provided with a suction port **15** (refer to FIG. **2**) formed therein as opened in an arc shape corresponding to the suction region of the pump chamber **7**. The side plate **6** is provided with a discharge port **16** formed therein as opened in an arc shape corresponding to the discharge region of the pump chamber **7**. Each of the suction port **15** and the discharge port **16** is preferably formed in an arc shape similar to that of each of the suction region and the discharge region of the pump chamber **7**, but may be formed in any shape as long as the suction port **15** is positioned so as to be communicated with the suction region and the discharge port **16** is positioned so as to be communicated with the discharge region.

Since the relative rotation of the pump cover **5** and the side plate **6** to the cam ring **4** is restricted by the support pin **13**, the position shift of the suction port **15** to the suction region and the position shift of the discharge port **16** to the discharge region are prevented.

The suction port **15** is formed in the pump cover **5** so as to be communicated with a suction passage **17** formed in the pump cover **5** to introduce the operating oil in the suction passage **17** into the suction region of the pump chamber **7**.

The discharge port **16** is formed in the side plate **6** so as to be communicated with a high-pressure chamber **18** formed in the pump body **10** to introduce the operating oil discharged from the discharge region of the pump chamber **7** into the high-pressure chamber **18**.

The high-pressure chamber **18** is defined by sealing a groove portion **10***d* formed as opened in a ring-shape to the bottom surface **10***b* in the pump fluid concave portion **10***a* by the side plate **6**. The high-pressure chamber **18** is connected to a discharge passage **19** (refer to FIG. **3**) formed in the pump body **10** for introducing the operating oil into the hydraulic equipment provided outside of the vane pump **100**.

The high-pressure chamber **18** is communicated through a narrow passage **36** (refer to FIGS. **1** and **3**) with the second fluid pressure chamber **32** and the operating oil in the high-pressure chamber **18** is regularly introduced into the second fluid pressure chamber **32**. That is, the cam ring **4** is all the time subjected to pressures in the direction of increasing the eccentric amount of the cam ring **4** to the rotor **2** from the second fluid pressure chamber **32**.

Since the high-pressure chamber **18** is formed in the pump body **10**, the side plate **6** is pressed toward the side of the rotor **2** and the vane **3** by pressures of the operating oil introduced into the high-pressure chamber **18**. In consequence, a clearance of the side plate **6** to the rotor **2** and the vane **3** is reduced to be small, thus prevent the leak of the operating oil. In this way, the high-pressure chamber **18** serves also as a pressure loading mechanism for preventing the leak of the operating oil from the pump chamber **7**.

The pump body **10** is provided with a valve accommodating hole **29** formed therein in a direction orthogonal to an axial direction of the drive shaft **1**. A control valve **21** is accommodated in the valve accommodating hole **29** for controlling pressures of the operating oil in the first fluid pressure chamber **31** and in the second fluid pressure chamber **32**.

The control valve **21** is provided with a spool **22** inserted into the valve accommodating hole **29** in such a manner as to slide freely therein, a first spool chamber **24** defined between one end of the spool **22** and a bottom portion of the valve accommodating hole **29**, a second spool chamber **25** defined between the other end of the spool **22** and a plug **23** sealing an opening of the valve accommodating hole **29**, and a return spring **26** serving as a urging member accommodated in the second spool chamber **25** for urging the spool **22** in a direction of expanding a displacement in the second spool chamber **25**.

The spool **22** is provided with a first land portion **22***a* and a second land portion **22***b* sliding along an inner peripheral surface of the valve accommodating hole **29**, and a circular groove **22***c* formed between the first land portion **22***a* and the second land portion **22***b*.

A first stopper portion **22***d* is located in the first spool chamber **24** so as to be connected to the first land portion **22***a*. The first stopper portion **22***d* abuts on the bottom portion of the valve accommodating hole **29** when the spool **22** moves in a direction of contracting a displacement in the first spool chamber **24**, thereby restricting the movement of the spool **22** within a predetermined region.

A second stopper portion **22***e* is located in the second spool chamber **25** so as to be connected to the second land portion **22***b*. The second stopper portion **22***e* serving as a movement restricting member abuts on the plug **23** when the spool **22** moves in a direction of contracting a displacement in the second spool chamber **25**, thereby restricting the movement of the spool **22** within a predetermined region. The return spring **26** is accommodated in the second spool chamber **25** so as to surround the second stopper portion **22***e*.

The control valve **21** is connected to a first fluid pressure passage **33** communicated with the first fluid pressure chamber **31**, a second fluid pressure passage **34** communicated with the second fluid pressure chamber **32**, a drain passage **35** communicated with the circular groove **22***c* and also communicated with the suction passage **17**, and a pressure introducing passage **37** (refer to FIG. **3**) communicated with the first spool chamber **24** and also communicated with the high-pressure chamber **18**.

The first fluid pressure passage **33** and the second fluid pressure passage **34** are formed inside the pump body **10** and also formed so as to penetrate through the adapter ring **11**.

The spool **22** stops in a position where a load by the pressures of the operating oil introduced into the first spool chamber **24** and the second spool chamber **25** defined in both ends of the spool **22** balances with an urging force of the return spring **26**. Depending on the position of the spool **22**, the first fluid pressure passage **33** is opened/closed by the first land portion **22***a* and the second fluid pressure passage **34** are opened/closed by the second land portion **22***b*, thereby supplying/discharging the operating oil in each of the first fluid pressure chamber **31** and the second fluid pressure chamber **32**.

In a case where a total load of the load by the pressure in the second spool chamber **25** and the urging force of the return spring **26** is larger than the load by the pressure in the first spool chamber **24**, the return spring **26** extends to position the spool **22** in a state where the first stopper portion **22***d* abuts on the bottom portion of the valve accommodating hole **29**. In this state, as shown in FIG. **1**, the first fluid pressure passage **33** is blocked up by the first land portion **22***a* of the spool **22** and the second fluid pressure passage **34** is blocked up by the second land portion **22***b* of the spool **22**. In consequence, communication between the first fluid pressure chamber **31** and the high-pressure chamber **18** is blocked and also communication between the second fluid pressure chamber **32** and the drain passage **35** is blocked.

Since a communicating passage **22***g* (refer to FIG. **3**) is formed in the first land portion **22***a* for communicating with the circular groove **22***c*, in a state where the first fluid pressure passage **33** is blocked by the first land portion **22***a*, the first fluid pressure chamber **31** is communicated with the drain passage **35** through the first fluid pressure passage **33**, the communicating passage **22***g* and the circular groove **22***c*. Since the operating oil in the high-pressure chamber **18** is all the time introduced through the narrow passage **36** into the second fluid pressure chamber **32**, a pressure in the second fluid pressure chamber **32** is larger than a pressure in the first fluid pressure chamber **31**, and the eccentric amount of the cam ring **4** to the rotor **2** is maximized.

In contrast, in a case where the load by the pressure in the first spool chamber **24** is larger than the total load of the load by the pressure in the second spool chamber **25** and the urging force of the return spring **26**, the return spring **26** is compressed and the spool **22** moves against the urging force of the return spring **26**. In this case, the first fluid pressure passage **33** is communicated with the first spool chamber **24** and is communicated through the first spool chamber **24** with the pressure introducing passage **37**. The second fluid pressure passage **34** is communicated with the circular groove **22***c* of the spool **22** and is communicated through the circular groove **22***c* with the drain passage **35**. Thereby, the first fluid pressure chamber **31** is communicated with the high-pressure chamber **18** and the second fluid pressure chamber **32** is communicated with the drain passage **35**. Accordingly, the pressure in the second fluid pressure chamber **32** is smaller than the pressure in the first fluid pressure chamber **31** and the cam ring **4** moves in a direction of decreasing the eccentric amount to the rotor **2**.

The communication between the second fluid pressure passage **34** and the circular groove **22***c* is made by a notch **22***f* formed in the second land portion **22***b* of the spool **22**. As a result, an open area of the drain passage **35** to the second fluid pressure chamber **32** increases/decreases in response to the movement amount of the spool **22**.

The control valve **21**, as described above, controls the pressure of the operating oil in each of the first fluid pressure chamber **31** and the second fluid pressure chamber **32** and operates with a pressure difference between before and after an orifice **28** interposed in the discharge passage **19**. The operating oil upstream of the orifice **28** is introduced into the first spool chamber **24** and the operating oil downstream of the orifice **28** is introduced into the second spool chamber **25**.

That is, the operating oil in the high-pressure chamber **18** is introduced through the pressure introducing passage **37** directly into the first spool chamber **24** without via the orifice **28** and is also introduced through the orifice **28** into the second spool chamber **25**. The orifice **28** may be constructed of either a variable type or a stationary type as long as the orifice **28** applies resistance to the flow of the operating oil discharged from the pump chamber **7**.

Next, an operation of the vane pump **100** constructed as described above will be explained with reference to FIGS. **4** and **5**. FIG. **4** is a hydraulic circuit diagram at the maximum discharge flow amount in the vane pump **100**. FIG. **5** is a hydraulic circuit diagram at the minimum discharge flow amount in the vane pump **100**.

When power of the engine is transmitted to the drive shaft **1** to rotate the rotor **2**, the pump chamber **7** expanded by and between the respective vanes **3** caused by rotation of the rotor **2** suctions the operating oil through the suction port **15** from the suction passage **17**. The pump chamber **7** contracted by and between the respective vanes **3** discharges the operating oil through the discharge port **16** into the high-pressure chamber **18**. The operating oil discharged into the high-pressure chamber **18** is supplied through the discharge passage **19** into the hydraulic equipment.

When the operating oil passes through the discharge passage **19**, a pressure difference occurs between before and after the orifice **28** interposed in the discharge passage **19**. The pressure upstream of the orifice **28** is introduced into the first spool chamber **24** and the pressure downstream of the orifice **28** is introduced into the second spool chamber **25**. The spool **22** in the control valve **21** moves to a position where a load caused by a pressure difference between the operation oil introduced into the first spool chamber **24** and the operation oil introduced into the second spool chamber **25** balances with an urging force of the return spring **26**.

Since a rotation speed of the rotor **2** is small at a pump starting time, the pressure difference between before and after the orifice **28** in the discharge passage **19** is small. Therefore, the spool **22** is, as shown in FIG. **4**, moved by the urging force of the return spring **26** to reach a position where the first stopper portion **22***d* forcibly abuts on the bottom portion of the valve accommodating hole **29**.

In this case, the communication between the first fluid pressure chamber **31** and the high-pressure chamber **18** is blocked and the first fluid pressure passage **31** is communicated through the communicating passage **22***g* formed in the first land portion **22***a* with the drain passage **35**. In addition, the communication between the second fluid pressure chamber **32** and the drain passage **35** is blocked. Here, since the cam ring **4** is subjected to the pressure in the direction of increasing the eccentric amount of the cam ring **4** to the rotor **2** by the operating oil in the high-pressure chamber **18** all the time introduced into the second fluid pressure chamber **32** through the narrow passage **36**, the cam ring **4** is positioned where the eccentric amount to the rotor **2** is maximized.

In this way, the vane pump **100** discharges the operating oil at the maximum discharge displacement and discharges a flow amount substantially in proportion to the rotation speed of the rotor **2**. Thereby, even in a case where the rotation speed of the rotor **2** is small, a sufficient flow amount of the operation oil can be supplied to the hydraulic equipment.

On the other hand, when the rotation speed of the rotor **2** increases, the pressure difference between before and after the orifice **28** in the discharge passage **19** becomes large. Therefore, the spool **22** moves against the urging force of the return spring **26**.

In this case, as shown in FIG. **5**, the first fluid pressure chamber **31** is communicated through the first spool chamber **24** with the high-pressure chamber **18** and also the second fluid pressure chamber **32** is communicated through the circular groove **22***c* with the drain passage **35**. Therefore, the operating oil in the high-pressure chamber **18** is supplied to the first fluid pressure chamber **31** and the operating oil in the second fluid pressure chamber **32** is discharged into the drain passage **35**. In consequence, the cam ring **4** moves in the direction of decreasing the eccentric amount of the cam ring **4** to the rotor **2** in response to the pressure difference between the first fluid pressure chamber **31** and the second fluid pressure chamber **32**.

The movement of the spool **22** causes an increase in a flow amount of the operating oil supplied to the first fluid pressure chamber **31** and also in a flow amount of the operating oil discharged from the second fluid pressure chamber **32**, but the movement of the spool **22** is restricted by the abutting of the second stopper portion **22***e* on the plug **23**. Therefore, the flow amount of the operating oil supplied to the first fluid pressure chamber **31** and also the flow amount of the operating oil discharged from the second fluid pressure chamber **32** are limited so as not to increase more than a predetermined value. In this way, the second stopper portion **22***e* acts in such a manner as to limit the discharge flow amount of the second fluid pressure chamber **32** when the eccentric amount of the cam ring **4** to the rotor **2** becomes small, and corresponds to a flow amount limiting member. Accordingly, the cam ring **4** slowly moves in a direction of decreasing the eccentric amount to the rotor **2**. By thus restricting the movement of the spool **22** by the second stopper portion **22***e*, it is possible to restrict the oscillation of the cam ring **4**, thereby restricting the variation of the discharge flow amount in the vane pump **100**.

Adjusting a length of the second stopper portion **22***e* causes the limitation of the flow amount of the operating oil passing through the control valve **21** at the time the eccentric amount of the cam ring **4** to the rotor **2** becomes small. That is, as the second stopper portion **22***e* becomes longer, the flow amount of the operating oil passing through the control valve **21** is reduced.

When the eccentric amount of the cam ring **4** to the rotor **2** becomes smaller, the outer peripheral surface of the cam ring

4 abuts on the swelling portion **12** in the inner peripheral surface of the adapter ring **11** to restrict the movement of the cam ring **4**. In consequence, the eccentric amount of the cam ring **4** to the rotor **2** is minimized and therefore the pump chamber **7** is to discharge the operating oil at the minimum discharge displacement.

In this way, the vane pump **100** is controlled to the pump discharge displacement in accordance with the pressure difference between before and after of the orifice **28** in the discharge passage **19** and the discharge displacement thereof gradually reduces in response to an increase of the rotation speed of the rotor **2**. In a case where the eccentric amount of the cam ring **4** to the rotor **2** is minimized, the vane pump **100** discharges the operating oil at the minimum discharge displacement. Thereby, the operating oil is appropriately controlled to be supplied to the hydraulic equipment at a vehicle running time.

In a state where the rotor **2** is being stopped, that is, the vane pump **100** is being stopped, the cam ring **4** stops at a position where the pressure in the first fluid pressure chamber **31** balances with the pressure in the second fluid pressure chamber **32**. Even in this case, the eccentric amount of the cam ring **4** to the rotor **2** does not become a zero or less because of the swelling portion **12** defining the minimum eccentric amount. Therefore, also at a starting time of the vane pump **100** when the power of the engine is transmitted to the drive shaft **1** to start the rotation of the rotor **2**, the vane pump **100** stably starts discharge of the operating oil.

As described above, at the pump starting time the vane pump **100** discharges the operating oil at the maximum discharge displacement by the operating oil in the high-pressure chamber **18** all the time introduced into the second fluid pressure chamber **32**. Even in a case where the discharge displacement thereof gradually reduces with an increase of the rotation speed of the rotor **2** and the eccentric amount of the cam ring **4** to the rotor **2** reaches to the minimum value, the vane pump **100** discharges the operating oil at the minimum discharge displacement because of the swelling portion **12**.

A discharge flow amount characteristic of the vane pump **100** is shown in a graph in FIG. **6**. In FIG. **6**, a lateral axis shows time and a longitudinal axis shows a discharge flow amount.

As described above, when the eccentric amount of the cam ring **4** to the rotor **2** becomes small, that is, when the discharge flow amount is reduced, by restricting the movement of the spool **22** by the second stopper portion **22***e*, the flow amount of the operating oil supplied to the first fluid pressure chamber **31** and the flow amount of the operating oil discharged from the second fluid pressure chamber **32** are limited. Therefore, as shown in FIG. **6**, the response at the time of reducing the discharge flow amount is degraded. However, since the cam ring **4** moves slowly as much as the flow amount limitation, the oscillation of the discharge flow amount can be sufficiently restricted.

Therefore, in the vane pump **100**, for improving the response at the time of increasing the discharge flow amount, it is possible to increase a flow passage area in the discharge passage of the operating oil in the first fluid pressure chamber **31** at the time the eccentric amount of the cam ring **4** to the rotor **2** becomes large. More specially it is possible to increase an open area of the communicating passage **22***g* formed in the first land portion **22***a*. Thereby, as shown in FIG. **6**, the response at the time of increasing the discharge flow amount is excellent.

Since the oscillation of the discharge flow amount at the time of decreasing the discharge flow amount is thus sufficiently restricted, the possibility of the oscillation in the discharge flow amount at the time of increasing the discharge flow amount is reduced even if the open area of the communicating passage **22***g* is increased. Therefore, it is possible to improve the response at the time of increasing the discharge flow amount.

There will be explained the reason the possibility of the oscillation in the discharge flow amount at the time of increasing the discharge flow amount is reduced even if the open area of the communicating passage **22***g* is increased. When the open area of the communicating passage **22***g* is large at the time the discharge flow amount is increased, the cam ring **4** quickly moves in a direction of increasing the eccentric amount. However, when the cam ring **4** swings back in a direction of decreasing the eccentric amount after that, since the movement of the spool **22** is restricted by the second stopper portion **22***e*, the cam ring **4** slowly moves. Therefore, the oscillation of the discharge flow amount is restricted at the time the discharge flow amount is increased. In this way, the second stopper portion **22***e* acts to restrict the oscillation of the discharge flow amount at the time the discharge flow amount is reduced and to restrict also the oscillation of the discharge flow amount at the time the discharge flow amount is increased.

As described above, the vane pump **100** shows the discharge flow amount characteristic that at the time of increasing the discharge flow amount, the response is excellent and also the oscillation of the discharge flow amount is restricted.

According to the above embodiment, the effect shown below can be achieved.

The vane pump **100** is provided with the second stopper portion **22***e* for limiting the discharge flow amount of the operating oil in the second fluid pressure chamber **32** at the time the eccentric amount of the cam ring **4** to the rotor **2** becomes small. Therefore, a rapid movement of the cam ring **4** can be restricted to restrict the oscillation of the discharge flow amount. Further, since the oscillation of the discharge flow amount is restricted by the second stopper portion **22***e*, it is possible to increase the open area of the communicating passage **22***g* as the discharge passage of the operating oil in the first fluid pressure chamber **31** for improving the response at the time of increasing the discharge flow amount. In this way, there is provided the variable displacement vane pump which can restrict the oscillation of the discharge flow amount and also improve the response at the time of increasing the discharge flow amount.

In a case where a rapid variation of the discharge pressure causes a rapid movement of the spool **22**, since the movement of the spool **22** is restricted by the second stopper portion **22***e*, an excessive compression of the return spring **26** can be controlled. As a result, the damage of the return spring **26** is prevented to improve a lifetime thereof.

Hereinafter, other embodiments in the present invention will be shown.

As the flow amount limiting member for limiting the discharge flow amount of the operating oil in the second fluid pressure chamber **32** at the time the eccentric amount of the cam ring **4** to the rotor **2** becomes small, an orifice **40** for applying resistance to the operating oil passing through the second fluid pressure passage **34** may be, as shown in FIG. **7**, provided instead of the second stopper portion **22***e*. Since the orifice **40** acts to limit the flow amount of the operating oil discharged from the second fluid pressure chamber **32** at the time the eccentric amount of the cam ring **4** to the rotor **2** is reduced, the orifice **40** achieves the same effect as the second stopper portion **22***e*.

For regularly introducing the operating oil in the high-pressure chamber **18** to the second fluid pressure chamber **32**, regular communication between the second fluid pressure chamber **32** and the second spool chamber **25** may be carried out instead of the provision of the narrow passage **36**. With this construction, the operating oil in the high-pressure chamber **18** is regularly introduced through the second spool chamber **25** into the second fluid pressure chamber **32**.

As shown in FIG. **8**, by abolishing the communicating passage **22**_g_ formed in the first land portion **22**_a_, the first fluid pressure passage **33** and the circular groove **22**_c_ may be constructed to be directly communicated with each other. In this construction, for increasing the flow passage area in the discharge passage of the operating oil in the first fluid pressure chamber **31** at the time the eccentric amount of the cam ring **4** to the rotor **2** becomes large, a thickness of the first land portion **22**_a_ is reduced.

Further, in the present embodiment, the swelling portion **12** is formed on the inner peripheral surface of the adapter ring **11** for preventing the eccentric amount of the cam ring **4** to the rotor **2** from being a zero or less. Instead of this swelling portion **12**, a spring for always urging the cam ring **4** in a direction of increasing the eccentric amount to the rotor **2** may be provided to be inserted into the adapter ring **11**.

While only the selected preferred embodiments have been chosen to illustrate the present invention, it will be apparent to those skilled in the art from this disclosure that various changes and modifications can be made therein without departing from the scope of the invention as defined in the appended claims. Furthermore, the foregoing description of the preferred embodiments according to the present invention is provided for illustration only, and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

What is claimed is:

1. A variable displacement vane pump having a rotor connected to a drive shaft, a plurality of vanes provided in the rotor so as to be capable of reciprocating in a diameter direction of the rotor, a cam ring for accommodating the rotor therein, the cam ring having a cam face in an inner surface thereof on which a front portion of the vane slides by rotation of the rotor and being made eccentric to a center of the rotor, and a pump chamber defined between the rotor and the cam ring, wherein an eccentric amount of the cam ring to the rotor changes, thereby changing a discharge displacement of the pump chamber, the variable displacement vane pump comprising:

a first fluid pressure chamber and a second fluid pressure chamber which are defined in an accommodating space in the outer periphery of the cam ring, wherein the cam ring is made eccentric to the rotor by a pressure difference between the first fluid pressure chamber and the second fluid pressure chamber;

a control valve which operates in response to a pump discharge pressure for controlling a pressure of an operating fluid in each of the first fluid pressure chamber and the second fluid pressure chamber;

a first fluid pressure passage communicated with the first fluid pressure chamber;

a second fluid pressure passage communicated with the second fluid pressure chamber; and

a flow amount limiting member for limiting a discharge flow amount of the operating fluid from the second fluid pressure chamber to a drain passage at the time the eccentric amount of the cam ring to the rotor becomes small by supplying the operating fluid to the first fluid pressure chamber through the first fluid pressure passage and discharging the operating fluid from the second fluid pressure chamber to the drain passage through the second fluid pressure passage.

2. The variable displacement vane pump according to claim **1**, further comprising:

an orifice for applying resistance to a flow of the operating fluid discharged from the pump chamber, wherein:

the control valve comprises:

a spool moving in response to a pressure difference between before and after the orifice;

a first spool chamber and a second spool chamber defined at both ends of the spool, wherein a fluid upstream of the orifice is introduced into the first spool chamber and a fluid downstream of the orifice is introduced into the second spool chamber; and

an urging member accommodated in the second spool chamber for urging the spool in a direction of expanding a displacement of the second spool chamber, wherein:

the spool moves to compress the urging member in such a manner that the operating fluid discharged from the pump chamber is supplied to the first fluid pressure chamber and the operating fluid in the second fluid pressure chamber is discharged with the increase of the rotation speed of the rotor; and

the flow amount limiting member includes a movement restricting member for restricting the movement of the spool in a direction of contracting the displacement of the second spool chamber.

3. The variable displacement vane pump according to claim **2**, wherein:

the movement restricting member includes a stopper portion which is arranged in the second spool chamber so as to be connected to the spool and abuts on an end of a valve accommodating hole in which the control valve is accommodated.

4. The variable displacement vane pump according to claim **1**, further comprising:

an orifice for applying resistance to a flow of the operating fluid discharged from the pump chamber, wherein:

the control valve comprises:

a spool moving in response to a pressure difference between before and after the orifice;

a first spool chamber and a second spool chamber defined at both ends of the spool, wherein the operating fluid upstream of the orifice is introduced into the first spool chamber and the operating fluid downstream of the orifice is introduced into the second spool chamber; and

an urging member accommodated in the second spool chamber for urging the spool in a direction of expanding a displacement of the second spool chamber, wherein:

the spool moves to compress the urging member in such a manner that the operating fluid discharged from the pump chamber is supplied through the first fluid pressure passage to the first fluid pressure chamber and the operating fluid in the second fluid pressure chamber is discharged through the second fluid pressure passage with the increase of the rotation speed of the rotor; and

the flow amount limiting member includes an orifice interposed in the second fluid pressure passage.

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